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Multicriteria analysis of sustainable development indicators in the construction minerals industry in China

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ABSTRACT

Mining and minerals is an important industry in China. Construction projects, in particular, are on the rise in Beijing. The construction minerals sector has already started responding to sustainability challenges, as demonstrated by the construction group. Thus, construction minerals are important in city development. The aim of this study was to develop a set of measurement and proposed hybrid method to analyze sustainable development indicators within economic categories under uncertainty. Evaluating the perceptions of sustainable indicators is a complex process because the requirements for environmental compliance tend to be vague and contradictory. In this study, the uncertainties in the evaluation process were resolved using a hybrid approach, which combines fuzzy set theory, the Delphi method, and a discrete multi-criteria method based on prospect theory for uncertainty (known as TODIM in Portuguese). The advantages of the developed hybrid approach are illustrated using a case study. The results show that the fuzzy TODIM approach can easily and effectively accommodate criteria for gain and loss functions, thereby enabling managers to improve sustainability indicators and reduce the overall environmental impact under uncertainty.

Introduction

The mining and minerals industry is vital to the supply of raw materials and economic development in many countries. Construction minerals (e.g., natural stone, aggregates, sand, gravel, and gypsum) are important for construction projects in Beijing. However, the extraction and processing of minerals pose challenges to sustainable development. The industry has responded to these challenges by incorporating boundary-spanning activities in upstream and downstream construction. Azapagic (2004) developed a sustainable framework consisting of economic, environmental, social and integrated indicators, which can be used internally (to identify hot spots), externally and in stakeholder engagement. Hashimoto et al. (2009) classified the material inputs of an economic society into four categories; this framework captures the key sustainable issues in the industry, but all of the mining and minerals issues must be converted into sustainable development indicators. There is an absence of literature on sustainable development indicators (SDIs) and economic studies on the construction mining industry in China (Basu et al., 2006; Yu et al., 2008; Tseng et al. 2009; Nikolaou and Evangelinos, 2010; Tseng, 2013).

Recently, many firms have not only been using standard financial indicators to track the effectiveness of their business but have also been including multiple stakeholders, such as customers, suppliers, employees, national regulators, firms, the local community, etc., in the process. Sustainability reports are emerging as a new trend in corporate reporting on the financial, environmental and social aspects of firms in supply chains (Krajnc and Glavič, 2005; Tseng et al., 2008; Tseng et al., 2014a). Construction mineral wastes currently account for 15% of the industrial wastes generated (Hashimoto et al., 2009). The Chinese government is creating opportunities for firms to learn from and to share innovations with their rivals via the supply chain. Firms also face institutional pressures on the domestic front. These pressures include normative pressures to satisfy the environmental requirements of stakeholders and the environmental activities of industrial professional groups (Liu and Buck, 2007; Zhu and Sarkis, 2007). Firms can evaluate their environmental impact in various ways: estimating the rate of emergence of construction mineral wastes, multiplying the amount of construction activity by the waste emergence rate per construction activity and estimating the amount of waste emerging from the construction minerals supplied at the time that structures are constructed (Cochran et al., 2007; Bergsdal et al., 2007; Hashimoto et al., 2007). Firms typically expect their resources to surpass environmental compliance and to develop efficient and product designs. Thus, the construction process needs to be investigated and SDIs must be determined for this process to lower wastes.

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Evidence shows that firms from different types of economies react differently to sustainable challenges (Meyer and Rowan, 1977; Anderson et al., 1994; Lin and Sheu, 2012). The social, economic, and political factors that constitute the institutional structure of a particular environment can offer firms advantages for engaging in specific types of activities there. Moreover, businesses that receive institutional support tend to perform more efficiently. One of the institutional views that has emerged is that institutions have developed to a similar isomorphism across organizations even though the institutions have evolved differently and that institutions have shaped the behavior of agents (i.e., suppliers, customers, regulators, etc.) (DiMaggio and Powell, 1983; Delmas, 2002; Delmas and Toffel 2008). In this study, institutional theory is redefined within an economic category such that a set of criteria can be applied to maximize environmental benefits for firms that are under normative pressures that cause firms to conform so that they are perceived as legitimate. Regulation-related governmental fines and trade barriers can also exert coercive and mimetic pressures on mining firms. How can management apply its knowledge of previous (successful and unsuccessful) ventures to support future decision-making from an institutional perspective?

There are very few studies from the institutional perspective in the literature: SDIs are always measured under the constraint of subjective human preferences (uncertainty), which has also not been thoroughly examined in the literature (Delmas, 2002, Azapagic, 2004; Delmas and Toffel 2008; Zhu et al., 2013; Tseng, 2013). The qualitative criteria are also littered with subjective perceptions because the evaluation criteria tend to be subjective, qualitative, or formulated in linguistic terms. Thus, it is extremely difficult for decision-makers to express their preferences using exact numerical values (Triantaphyllou and Lin, 1996; Tseng et al., 2008, 2009). Using SDIs with a set of assessment attributes generally results in a highly subjective and unstructured evaluation of the criteria because the managers' experience, knowledge, and intuition are relied upon significantly. The use of SDIs has given firms a significant competitive advantage and is expected to remain an important component of their business strategy in the future.

However, firms cannot consider all of the relevant attributes because of bounded rationality and a limited capacity for information processing. Thus, the evaluation approach is often ineffectively implemented because the firm does not effectively use its knowledge of previous experiences in prioritizing SDIs. SDIs are a measure of the deeper and more resilient features of a social structure. SDIs are used to consider the processes by which structures, including economic schemes and routines, become established as authoritative guidelines for social behavior. Thus, institutional theory was used in this study within the context of economic categories (Chou and Chang, 2008; Tseng, 2011b). How can SDIs be aligned with the classification of an economic category and under vague and subjective criteria that are subject to uncertainty?

The objective of this study was to create a mechanism to aid management in analyzing and ranking the economic input alternatives for SDIs. Such a mechanism can enable a firm to make decisions in a systematic, clear and wide-ranging manner and to consider a wider and more diversified base of primary criteria that critically influence managers' choices and recommendations. To demonstrate the effectiveness of the developed hybrid multi-criteria analysis in facilitating the evaluation process, a case study was conducted on a focal construction firm in the industry, which greens processes by frequently applying new technologies that are critical for successful sustainable management. This paper is divided into three primary sections. First, the fundamentals of fuzzy set theory and TODIM are introduced. Next fuzzy set theory is integrated with TODIM. The detailed development of the economic category in the evaluation of SDIs in a focal firm and the associated results are presented. Finally, the feasibility and the practicality of this approach are analyzed and discussed, and plans for further work are outlined.

Study rationale

External stakeholders can exert pressure on firms to further environment protection even though environmental regulations and mandatory programs have already been implemented. Stakeholders typically expect firms to surpass environmental compliance standards and to develop efficient designs. Different industries have different levels of competition, uncertainty and technology development, and thus, individual firms in different industries face environmental challenges of different types and intensities. In addition, SDIs are expected to assess the life cycle of a product using gain and loss functions from prospect theory. Hilson and Basu (2003) identified the vagueness of these measures and their related interpretations, which have been increasingly emphasized in national, international and environmental policies. Nevertheless, a firm's environmental process must satisfy SDIs under the constraint of subjective human preferences (i.e., uncertainty), a phenomenon that has not been thoroughly investigated (Lyon and Maxwell, 2000, Zhu and Geng, 2001; Zhu and Sarkis, 2006; Zhu et al., 2008).

Basu et al. (2006) analyzed various approaches in the current literature and presented an emerging industrial ecology framework that can be adopted by the manufacturing, construction, and process industries to provide innovative solutions in strategic planning that lead to cleaner operation and production and can achieve sustainable development for pollution prevention at the corporate and operational levels. These policies emphasize waste minimization, recycling, pollution control, and waste disposal activities at the operational level. Implementing these policies involves integrating the environmental management system, cost accounting and the assessment of environmental benefits. In a practical analysis, Hashimoto et al. (2009) used fundamental knowledge to analyze environmental impacts and resource losses and estimated the annual share of potential wastes and secondary resources in the total demand for construction minerals at approximately 30% for recent years and approximately 40% in the past. Büyüközkan and Çifçi (2012) noted that a firm's environmental performance is not only related to internal environmental efforts but also to the stakeholders' perception of the firm's environmental performance and image.

An earlier impetus for sustainable development called for the development of sustainable development indicators to provide solid bases for decision-making at all levels and to facilitate self-regulatory sustainability by which environmental considerations could be integrated into existing systems. When industrial growth is rapid, SDI programs always tacitly assume that individuals and organizations act based on rational and informed decision-making. Hilson and Basu (2003) studied one aspect of the mining and minerals sustainable development debate: the corporate perspective. First, the burgeoning literature was used to define sustainable development within the corporate mining context; this background was then used to identify many of the salient issues associated with developing a series of SDIs for the mining and minerals extraction industry. Sustainable development is currently required to balance the objectives of all of the environmental securities against economic development and environmental protection. Thus, sustainable policies should focus on the efficient use of limited resources and the development of environmentally friendly approaches from all perspectives (Hezri and Hasan, 2004; Tsai, 2010).